5G Mobile, an Overview by **Stephen Hearnden** on 26 June 2020

Mr Hearnden, now retired, had a career in telephony, notably as the Chief Technology Officer with Cellnet (now O2). He briefly described the development of mobile telephony from its start in 1985.

It was then that analogue Cellular telephony was launched in the UK. It cost £25 a month with usage at 25p per minute. Handsets were dubbed 'bricks', and there were health worries from microwave radiation by mobile phone users or to people near masts.

- **GSM** (Groupe Speciale Mobile, later Global System for Mobile), the second generation, followed in 1991; this featured more secure telephony because it was digital and encrypted. It also provided a messaging service called SMS, limited to 160 characters, and could handle low speed data 2.4kb/s up to 9.6kb/s (rarely).
- **3G**, the third Generation (UMTS – 'U' for Universal) came 10 years later but was not a success; it offered telephony and theoretically internet access. It was oversold; Ofcom auctioned licences to operate, with four operators bidding – each coughed up £4bn which left them starved of money to develop the service. The speeds, after various upgrades, peaked at 384kb/s, although some operators offered more; customers complained about slow speeds and intermittent access. Coverage was never complete – Ofcom measured it by land area, while operators measured it by proportion of people served. Operators' figures for coverage tend to assume optimum conditions seldom found in real life. Even in London there were 'not spots'.
- **4G** was launched c.2011 with a very different network architecture. It was the first mobile system featuring all Internet Protocol (IP) - speech is divided into packets, each packet having a destination address, the speech only reconstituted at the destination – there is no single end-to-end circuit switched route. It uses the Long-Term Evolution (LTE) standard for wireless broadband communication for mobile devices agreed by the European Telecommunications Standards Institute (ETSI).

4G was first introduced to the UK in 2012, with EE rolling out its 4G services to 11 major cities including London, Manchester, Bristol, Birmingham, Cardiff, Edinburgh, Leeds, Liverpool, Sheffield, Glasgow and Southampton; this is the technology used to access the mobile internet today. Again coverage is not universal despite Government exhortations, the fallback being 3G.

Both 4G and WiFi use IP, so why should a business provide WiFi if 4G is available? Answer - average usage of a WiFi installation is 190 GB/month per household, while 4G provision 5.8 GB/month per user.

Download speeds for a full HD film:	3G at	8 kb/s average	384 kb/s max	over a day
	4G	32.5 Mb/s ave	100 Mb/s max	over 7 min
	4G+	42 Mb/s ave	300 Mb/s max	2.5 min
	5G	130 Mb/s ave	1 Gb/s max	40 sec
	5G (theoretical)	240 Mb/s ave	10 Gb/s max	4 sec

- **5G** arrived in 2018. The International Telecommunication Union (ITU), based in Switzerland, sets internationally agreed standards, to ensure compatibility. The ITU-R ('R' for Radio) has set an open standard for 5G, which any equipment designed for it must meet; and has defined three main uses for 5G: enhanced Mobile Broadband (eMBB); Ultra Reliable Low Latency Communications (URLLC); and massive Machine Type Communications (mMTC).
  - eMBB uses 5G as a progression from 4G LTE mobile broadband services, with faster connections, higher throughput, and more capacity. Usage is envisaged for 4K HD Television, Smart Homes, Gaming; Autonomous Vehicles; Smart Cities; inter-stock exchange Banking; and applications in Industry; and Medicine. Mr Hearnden gave several examples of what 5G could do: affordable home surveillance from anywhere in the world; Milton Keynes becoming a smart city; a surgeon in Oxford directing an operation in London.
  - URLLC refer to using the network for mission critical applications that require uninterrupted & robust data exchange. (Latency is the time between initiation and response eg a lightning flash and

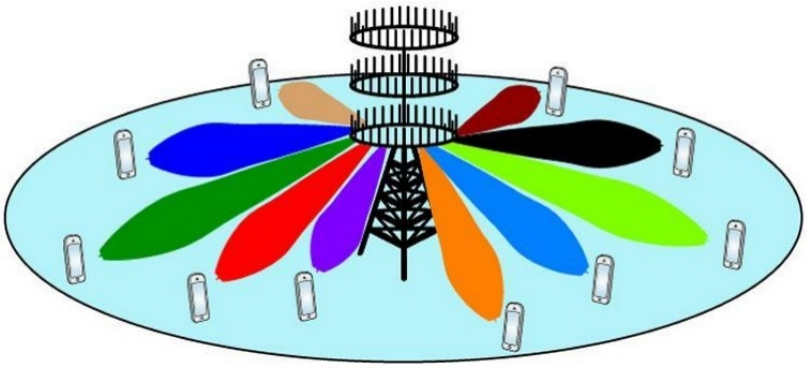
the thunder clap). Approximate network latency times for 3G are 65ms; 4G 40-50ms; and 5G 1ms (theoretical), though <20-30ms for more ordinary applications. Low latency is vital for many machine-to-machine applications.

- mMTC would be used to connect to a large number of low power, low cost devices with high scalability and increased battery lifetime, in a wide area. Ford and Vodafone are devising a factory communication system between automated machines using 5G. A totally different scheme is being devised to monitor sheep on Dartmoor where sheep rustling is a problem - each sheep having its own tag (this is better than if done with an RFID approach as more data could be transmitted). In the meantime, until 5G coverage is available, the use of WiFi is being trialled.

Network Architecture

An area is served by a 'Macrocell' with backhaul connection to the network core, and probably further relay connection(s) to other macrocell(s); depending on need there could also be Microcells, or Picocells within the area, also with backhaul connections. Femtocells could also be used, with backhaul connection via the Cloud. With the increasing use of mobile data smaller and smaller cells are required requiring more sophisticated RF techniques.

Massive MiMo or multiple input multiple output. The diagram is of a central mast serving a number of telephones. It is equipped with an array of aerials which can be programmed to produce several beams, each directed to a particular phone. Each of the beams can communicate with its phone even though all the beams are at the same frequency.



Standard MiMo networks tend to use two or four antennas. Massive MIMO, on the other hand, can have tens or even hundreds of antennas. For example, Huawei, ZTE, and Facebook have demonstrated Massive MiMo systems with as many as 96 to 128 antennas; Ericsson's AIR 6468, which the company claims is "the world's first 5G NR radio", uses 64 transmit and 64 receive antennas.

The advantage of a Massive MiMo network over a regular one is that it can multiply the capacity of a wireless connection without requiring more spectrum. Current mobile networks are rather dumb in the way they apportion a single pool of spectrum between all users in the vicinity, which results in a performance bottleneck in densely populated areas. With Massive MiMo and beamforming such a process is handled far more smartly and efficiently, so data speeds and latency will be far more uniform across the network.

Reports point to considerable capacity improvements, potentially a 50-fold increase. A Massive MiMo network will also be more responsive to devices transmitting in higher frequency bands, which will improve coverage. In particular, this will have considerable benefits for obtaining a strong signal indoors (though 5G's higher frequencies will have their own issues in this regard). The greater number of antennas in a Massive MiMo network will make it far more resistant to interference or intentional jamming than current systems.

Telephone Handsets have internal aerials designed not to unduly irradiate the user, limiting their ultimate sensitivity. They also have several receivers to cope with differing frequency bands – each band served comes with a 1dB penalty in sensitivity; Mr Hearnden suggested a number of bands up to 10. Today there are a few 5G telephones, costing £500 or more (most others are only 4G, not 5G ready). Apple are still working on it.

The current UK position: there are 4 licensed operators - O2, Vodafone, EE and ***3***. The first auction of 5G spectrum concluded in April 2018 when Ofcom sold 150MHz of 3.4GHz spectrum previously used by the Ministry of Defence (MoD) to the 4 mobile operators and UK Broadband; Ofcom also auctioned off 40MHz of 2.3GHz spectrum (also recovered from the MoD) for immediate use to provide additional capacity for 4G networks, which can also be used for 5G in the future. O2 won all the available 2.3GHz spectrum.

The future UK position: Ofcom was to auction the 700MHz spectrum with applications expected to begin in December 2019, the process complete by Spring 2020. 80MHz of this band will be auctioned, alongside 120MHz in the 3.6-3.8GHz band, 200MHz of spectrum in total. This has been delayed due to rule changes in rural areas to ensure they will be covered adequately. A new Shared Rural Network (SRN) has been established to allow further cost saving with shared sites, masts etc – this flouts EU competition regulations.

Mr Hearnden concluded by saying that 5G gives an opportunity to deliver full mobile high speed services.

But its success relies on good coverage everywhere (*not proven yet*). Will there be an appetite for these services or are the technologists just hyping it up? 3G was not a success - could 5G go the same way?

There is adequate spectrum to deliver competitive services. It will be 3-5 years before we know whether 5G is successful or not. People, happy with what they have, are not replacing their phones so often.

Emergency Services: in answer to a question, Mr Hearnden said the Police (& others) used a Motorola system in Band 3 at 180-230MHz – they do not have to compete in emergency conditions with anxious people using the resources of the local public mast.